FACULTY WORKING PAPER 92-0109

Graphic Measures of Decision Processes

Eloise Coupey
Department of Business Administration
University of Illinois

Mark T. Jones
Argonne National Laboratory

Bureau of Economic and Business Research
College of Commerce and Business Administration
University of Illinois at Urbana-Champaign

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February 1992

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Eloise Coupey
University of Illinois at Urbana-Champaign

and

Mark T. Jones
Argonne National Laboratory

ABSTRACT

Graphic measures of process-level data provide the researcher with a method for visualizing decision processes. Three graphic measures of decision processes are developed and described, using data collecting from subjects engaged in a consumer choice task. These measures have several advantages compared with standard process measures. 1) Graphic measures do not reduce process data to single summary statistics, thus avoiding the possibility of misrepresenting the decision process. 2) Graphic measures can reveal information about shifts in processing strategies. 3) Graphic measures can be used to examine intuitions about decision processes for exploratory research. 4) Graphic measures can be used to check the validity of standard, summary measures.

GRAPHIC MEASURES OF DECISION PROCESSES

INTRODUCTION

Graphic measures are a valuable tool for researchers who need to utilize process-level data. Graphic measures differ from standard process measures in that they do not attempt to reduce the entire decision process to a single summary statistic (Ford, Schmitt, Schechtman, Hults, and Doherty, 1989).

An obvious advantage of graphic measures is that they allow researchers to visualize changes in subjects' strategies over the course of a decision. For example, suppose that a consumer who wants to buy a car begins to make the decision using a purely lexicographic, noncompensatory rule: "Economy is the most important feature to me, so I'm only going to consider mileage in making my decision." After narrowing the field of alternatives to four cars, the consumer decides to also consider performance, safety, and comfort in making a final choice: "I'm going to say that these four features are equally important to me, and the final rating for each car will be a total valuation of the car's goodness on all four features." The final purchase decision was made using a compensatory rule, even though the consumer began with a noncompensatory rule. Standard process tracing measures, such as the direction of search (i.e., within-attribute or within-alternative), could result in a summary measure indicating that the final decision was made using a noncompensatory rule, if the number of cars evaluated initially was greater than the number of cars times the number of features considered in the second stage of the decision. Such a finding would misrepresent the evaluation process, leading an observer of the decision process to draw inaccurate and misleading conclusions about the nature of consumer decision behavior.

One way to avoid the possibility of misinterpreting decision behavior is to take advantage of the process tracing data that is available from most of the standard process tracing methods. In addition to the summary measures obtained by distilling detailed process data into single statistics, researchers could, and should, use graphic measures of process data to construct visual depictions

of decision processes. Such measures reflect characteristics of processing, such as switches among decision rules, that may often be swallowed up by summary measures. These measures can be used to examine intuitions about decision processes for exploratory research. If necessary, the researcher can then design summary measures that are suitable to a particular situation. Graphic measures can also be used to check the validity of standard, summary measures.

The remaining sections of this paper detail a first step at developing graphic measures of decision behavior for one type of process data, the pattern of processing. These measures were initially developed to describe the behavior of subjects engaged in a decision making task (Coupey, 1990). Pattern of processing refers to whether consumers tend to examine information by attributes or by alternatives. Pattern information is often used as an indicator of compensatory or noncompensatory choice processing (Billings and Marcus, 1983; Payne, Bettman, Johnson, and Coupey, 1990; Todd and Benbasat, 1989). As a result, it is an extremely important measure for decision researchers.

GRAPHIC MEASURE DEVELOPMENT

Payne's Pattern of Processing Measure

Payne (1976) demonstrated the use of a summary measure designed to reflect whether decision processing is attribute-based or alternative-based. Assume that a display of information can be represented as a brand/attribute matrix. Information can be gathered within brands (alternative-based processing) or across brands (attribute-based processing). Payne's measure summarizes a pattern of acquisitions by creating an index of two types of transitions: 1) within-alternatives, and 2) within-attributes. Each time a type of transitions occurs, it it assigned a value of +1. The summary measure is then computed by the formula:

$$\text{PATTERN} = \frac{\text{alternative-based transitions} - \text{attribute-based transitions}}{\text{alternative-based transitions} + \text{attribute-based transitions}}.$$

The resulting values of PATTERN are bounded by +1 and -1, where +1 indicates purely alternative-based processing, and -1 indicates purely attribute-based processing.

The idea of creating an index to reflect processing is broadened in this paper to create graphic measures of processing which reveal processing behavior throughout the decision.

Graphic Measures of Choice Processing

Three graphic measures of choice processing were developed, RUNDEX, TIMEDEX, and PAIRDEX. The measures provide insights into decision behavior by enabling plots of transitions between brands and attributes, where the x-axis may be either the running count of acquisitions or the current time in the decision. RUNDEX and TIMEDEX are conceptual descendants of the pattern measure developed by Payne (1976). RUNDEX is useful for examining acquisition behavior, because it enables the researcher to plot transitions between acquisitions, using equally weighted transitions. TIMEDEX extends the RUNDEX approach by using the amount of time spent on each transition, enabling inferences about processing strategies. The third measure, PAIRDEX, is an entirely new depiction of a common choice process, pairwise processing. These measures can also be distilled into single summary measures for every subject, similar to Payne's original pattern index.

The graphic measures were developed using process data obtained with Mouselab, a computer-based, process tracing system (Johnson, Payne, Schkade, and Bettman, 1989). Mouselab tracks the number and sequence of acquisitions, as well as the time spent per acquisition, and the time spent moving from one piece of information to the next. The measures are not limited to Mouselab data, however. They may be used with many of the standard forms of process monitoring, such as verbal protocols (e.g., Bettman and Park, 1980), information display boards (Svenson, 1979), and eye movement monitoring (Russo and Rosen, 1975). The only requirements are that the researcher be able to collect sequence data (for all measures) and elapsed time data (for TIMEDEX). To simplify the description of measure construction, choice displays are described as brand/attribute matrices, where brands are the row elements, and attributes are the column elements.

RUNDEX

RUNDEX is derived from Payne's pattern measure and gives a box-by-box description of the subject's acquisitions throughout the decision. Using RUNDEX to describe processing behavior enables the experimenter to see when the subject moves from attribute-based behavior to alternative-based behavior, and vice-versa. RUNDEX is a running index calculated by subtracting the most recent transition value (+1.0 for an alternative-based transition; -1.0 for an attribute-based transition) from the cumulative total. The indices are bounded by -1 and +1. Each current running index value can be plotted against the current number of acquisitions, or against the current amount of elapsed time in the decision.

From RUNDEX, a corollary measure, PROCDIFF, was constructed. PROCDIFF provides a second dynamic view of processing style, enabling plots which reveal the degree to which a subject is consistent in his or her use of attribute- or alternative-based processing. PROCDIFF values are calculated by subtracting the current number of alternative-based transitions from the current number of attribute-based transitions for every new transition. When these values are plotted against the count of acquisitions or the current time in the decisions, the researcher can use the plotted slope/s to gauge consistency of processing style. A plot that begins at +1.0 and then decreases monotonically through all acquisitions indicates that the subject relied solely upon attribute-based acquisitions to make his recommendation. A monotonically increasing plot indicates solely alternative-based processing. A combination of slopes indicates that the decision maker processed information by attribute in some portions of the decision, and by alternative at other times in the sequence of acquisitions. Therefore, changes in slope can be interpreted to mean changes in acquisition strategy of decision phase. Figure 1 contains sample plots for RUNDEX and PROCDIFF. Panel A contains the plot of RUNDEX against COUNT. The plotted values are all below zero, indicating predominantly attribute-based processing. Detailed inspection reveals that the decision maker became increasingly attribute-based in processing during the first half of the decision. In the latter half of acquisitions, the decision maker shifted toward alternative-based

processing. Despite the shift, however, the processing remains largely attribute-based. In addition, the decision maker switched from attribute-based processing to alternative-based processing at several points in the decision. These points are shown by abrupt changes in slope. For example, crooks in the curve at forty-five and fifty-five acquisitions reflect strategy shifts.

The plot of PROCDIFF bears out the suggestion that processing is mainly attribute-based. The downward slope of the plot indicates that the decision maker was very consistent in the use of an attribute-based strategy. The straight line is fitted through the plotted values using least squares regression. The dashed curves represent 95% confidence limits for the line of fit. The closeness of the confidence curves to the line of fit suggests fairly consistent processing.

Insert Figure 1 about here.

The main conceptual distinction between RUNDEX and PROCDIFF is in the interpretation of slope. For RUNDEX, increases or decreases in the plotted curves indicate that the decision maker's behavior became more or less alternative-based. For PROCDIFF, an increase in slope does not mean that the decision maker became more alternative-based during the decision. Rather, the increase merely means that the decision maker was consistent in the use of a processing style.

The procedure for constructing RUNDEX is:

1) Determine numbers of within-alternative and within-attribute transitions:

2) Sum within-alternative and within-attribute transitions:

alt sum_i= # of within-alternative transitions up to and including step *i*

att sum_i= # of within-attribute transitions up to and including step *i*

3) Compute the index using the sum values:

$$\text{Rundex} = \frac{\text{alt sum}_i - \text{att sum}_i}{\text{alt sum}_i + \text{att sum}_i}$$

TIMEDEX

TIMEDEX is formulated in the same manner as RUNDEX. TIMEDEX differs from RUNDEX in that the definition of transitions is based upon the amount of time spent moving within an attribute or within an alternative, rather than equally weighting all transitions, as RUNDEX does. The rationale behind TIMEDEX is that a decision maker does not spend the same amount of time on all transitions. For example, a decision maker carrying out an elimination-by-aspects rule inevitably accumulates several alternative-based transitions when moving from column to column (specifically, the number of attributes minus one). These alternative-based transitions are not really a part of the decision maker's processing strategy, and their inclusion in a summary pattern measure or RUNDEX can be misleading for inferring choice processing strategies. The time spent within a box and moving to the next piece of information can be used to remedy this problem. It is expected that decision makers will spend less time on transitions completed merely to get to the next piece of information that is a part of a processing strategy than they will making transitions and examining box information that is part of the strategy. By using the elapsed time from entry of one box to entry of the next box to calculate transitions instead of counts of acquisitions, a picture of processing can be drawn that is not distorted by transitions that are, to the subject, unimportant in his evaluation of the information.

To illustrate the potential advantage of TIMEDEX over RUNDEX for inferring processing strategy, suppose that a decision maker carries out an attribute-based strategy of going down one attribute and across the the next, then up and across to the third attribute. RUNDEX would count the transitions between attributes as alternative-based transitions and would weight them equally in the plot to reflect search and acquisition behavior. If, however, the decision maker is spending more time processing information in the attributes and is very swiftly crossing to the next attribute, these time differences would be registered by TIMEDEX.

TIMEDEX's partner measure, PROCTIME, is the time-based analog of PROCDIFF. Figure 2 has sample plots for TIMEDEX and PROCTIME, for the same data as in Figure 1. Notice that the plotted values for processing early in the decision show a markedly steeper

attribute-based slope than do the early values for RUNDEX. The TIMEDEX plot indicates that the decision maker started with more alternative-based processing than does the plot for RUNDEX. In addition, TIMEDEX suggests that the processing strategy used by the decision maker was generally more alternative-based than the strategy indicated by the plot of RUNDEX. This means that some attribute transitions done merely to shift between alternatives, such as at the beginning and end of rows, were given more weight in the RUNDEX measure than they really deserve.

Insert Figure 2 about here.

The procedure for computing TIMEDEX is identical to the one given for RUNDEX, with the single exception that plustimes are used to weight the transition types.

1) Determine transition type:

2) Compute the sums of the transitions times:

alt time sum_i= time spent processing within-alternatives up to and including step *i*

att time sum_i= time spent processing within-attributes up to and including step *i*

3) Compute the index:

$$\text{Timedex} = \frac{\text{alt time sum}_i - \text{att time sum}_i}{\text{alt time sum}_i + \text{att time sum}_i}$$

PAIRDEX

The third measure developed to examine processing is PAIRDEX. PAIRDEX, plotted against count, reveals the amount of pairwise processing done in a decision. PAIRDEX was developed to assess choice processing that is neither predominantly alternative-based nor predominantly attribute-based. The summary pattern measure and its dynamic variants, RUNDEX and TIMEDEX, were not designed to measure the amount of pairwise processing carried out. As a result, strategy type assignments based on pattern-type measures cannot indicate when decision

makers do pairwise processing. For example, pairwise processing could be done in two ways. The decision maker could process in a pairwise manner by looking at the value of an attribute on one brand and comparing it with the same attribute's value on a second brand. If the decision maker repeats this procedure for all of the attributes, eliminating the brand with the greater number of dominated attributes, the summary pattern value would be close to -1, indicating very attribute-based processing. Alternatively, the decision maker could begin similarly by looking at an attribute on one brand, and then comparing it with the value for the same attribute on the next brand. However, instead of returning to the first brand to begin the next comparison, the decision maker might move to the second attribute on the second brand, and then up to the same attribute on the first brand. This would be reflected in the standard pattern measure as a greater number of within-alternative transitions, and a pattern index value closer to +1, than in the first example. In short, two different methods for carrying out the same process of pairwise comparisons could result in different pattern-based assignments of strategy type. PAIRDEX was developed to address this concern, and it reflects the amount of pairwise processing done in a decision in either manner.

PAIRDEX is calculated by looking at the last two acquisitions relative to the current acquisition. If the current acquisition is in the same row, or alternative, as either of the two previous acquisitions, the transition is coded as a pair transition. This method of defining transitions accounts for the possibility that a decision maker can be carrying out a pairwise process by comparing a currently preferred brand with another brand, attribute by attribute. A running index that may be used to plot processing is generated when, for each acquisition, the cumulative number of non-pairwise transitions is subtracted from the cumulative number of pairwise transitions, and the current difference is divided by the sum of all transitions to provide a standardized value between -1 and +1. When these indices are plotted against the counts of acquisition, positive slopes indicate that the decision maker is becoming more pairwise in processing decision information than non-pairwise. Negative slopes indicate a tendency to non-pairwise processing behavior.

As with RUNDEX and TIMEDEX, procedural consistency may be assessed by subtracting the cumulative value of non-pairwise transitions from the cumulative value of pairwise transitions, and plotting the resulting differences against the cumulative counts of acquisitions. A plot of PAIRDEX and a plot of the pairwise difference measure, PAIRDIFF, is shown in figure 3 for a decision maker who used a pairwise strategy for the first half of the decision.

Insert Figure 3 about here.

The procedure for computing PAIRDEX is:

1) Compute the sums of pairwise and non-pairwise transitions:

$pairwisesum_i$= # of pairwise transitions up to and including step *i*

$nonpairsum_i$= # of non-pairwise transitions up to and including step *i*

2) Compute the index:

$$\text{Pairdex} = \frac{\text{pairwisesum}_i - \text{nonpairsum}_i}{\text{pairwisesum}_i + \text{nonpairsum}_i}$$

A time-based counterpart of the PAIRDEX measure can be constructed with the same method that TIMEDEX was computed from RUNDEX. Plustimes would be used to calculate the pairwise and nonpair sums, rather than equally weighting the two types of transitions.

SUMMARY AND CONCLUSIONS

The use of visualization methods in decision research is an often-overlooked source of information. The importance of developing and using graphic measures is reflected in the widespread, interdisciplinary applications of visualization techniques.

Three graphic measures of choice processing were presented to illustrate the value of using the full range of process data to describe processing behavior in consumer decision making. These

measures provide a visual depiction of the process throughout the course of the decision. As a result, they provide a more detailed, and potentially more accurate, description of the process than a single, summary measure. The validity of the graphic measures is underscored by the use of real data in their development; all of the examples and plots of RUNDEX, TIMEDEX, and PAIRDEX in this paper were obtained from subjects' process tracing data.

Attention should be given to the development of additional graphic measures with which to examine intuitions, develop theories, and validate conclusions based on summary data.

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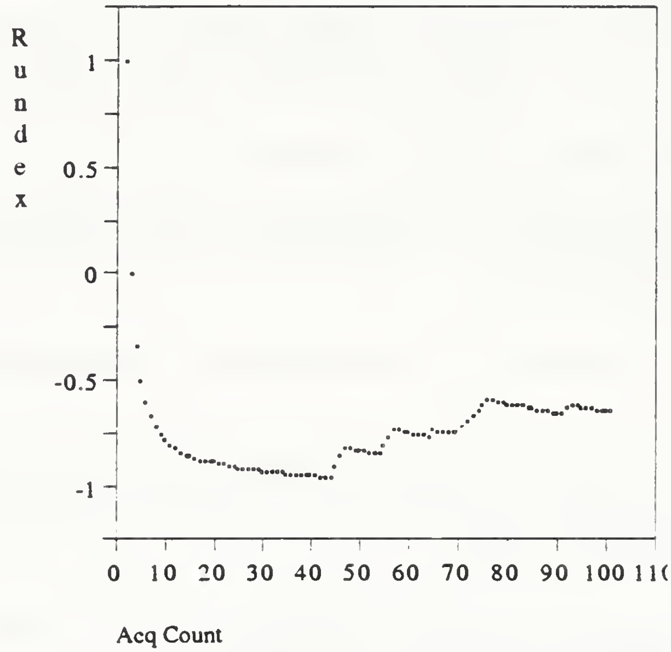
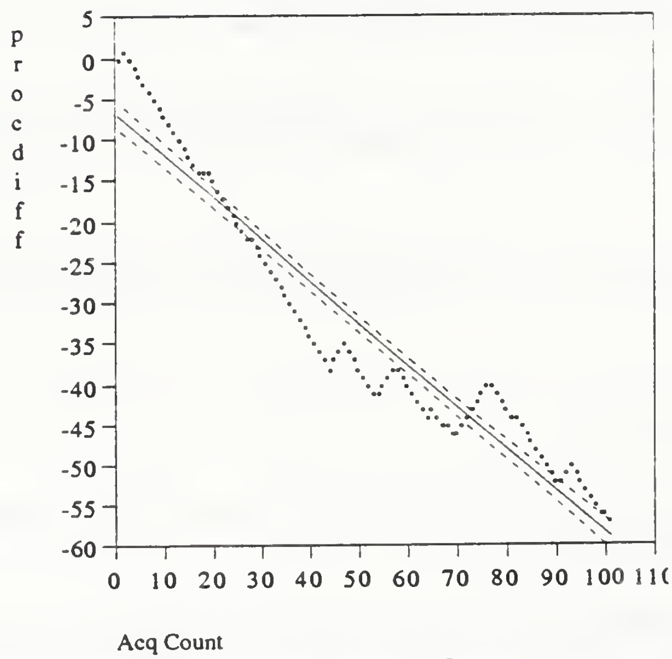
Figure 1

SAMPLE PLOTS OF RUNDEX AND PROCDIFF



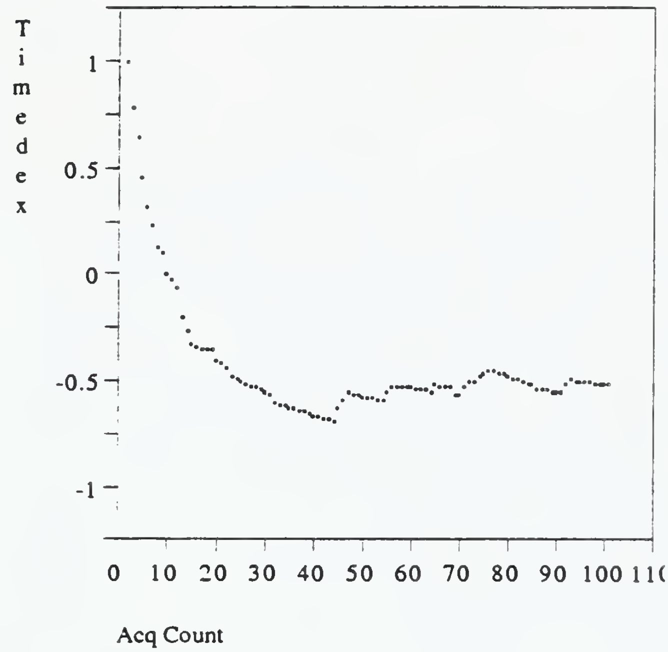
Panel A



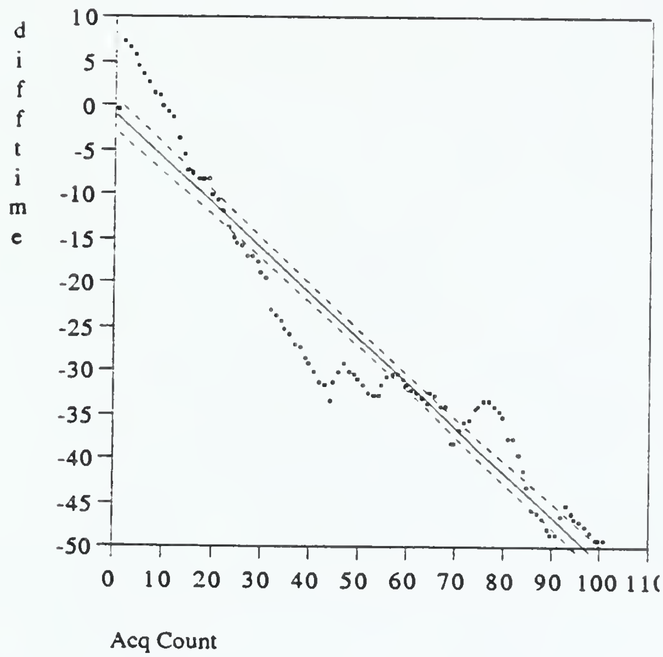
Panel B

Figure 2

SAMPLE PLOTS OF TIMEDEX AND DIFFTIME



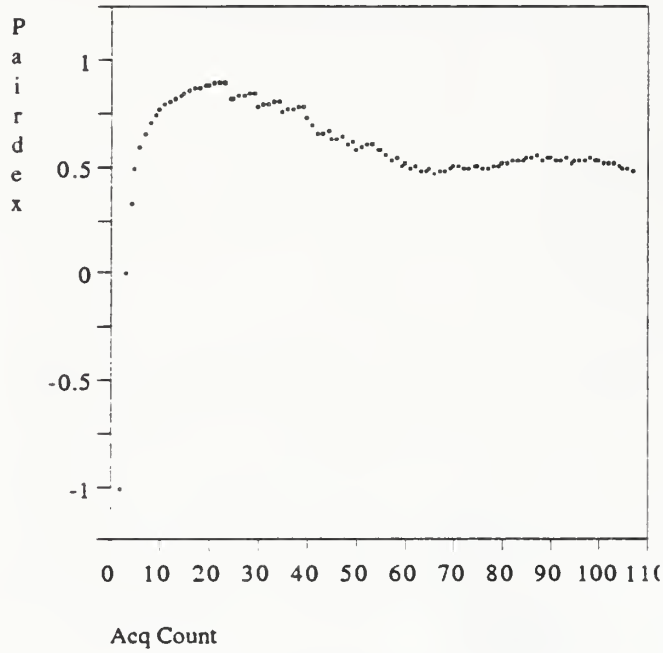
Panel A



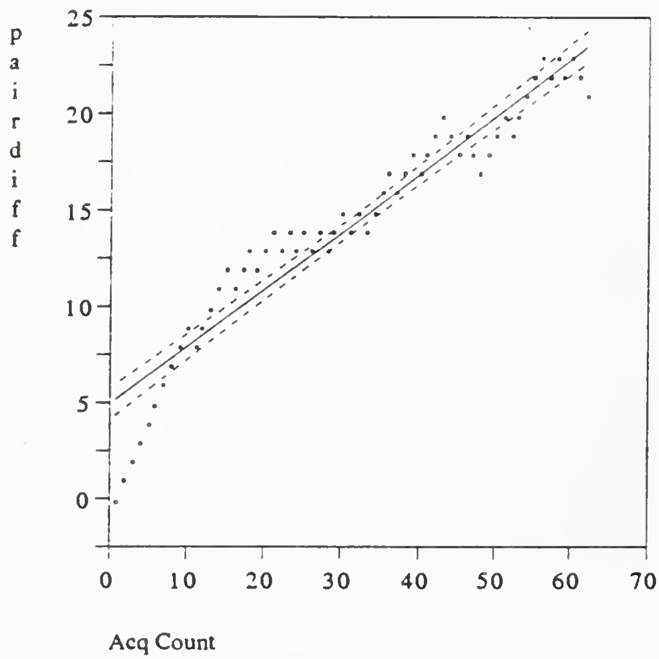
Panel B

Figure 3

SAMPLE PLOTS OF PAIRDEX AND PAIRDIFF



Panel A



Panel B